hood, and the field experiments are carried out on farms in all parts of the county, this system having the double advantage that manurial trials can be made on every class of land, and that farmers in each district are able to see for themselves the results.

## THE NEWCOMEN ENGINE.[1]

A GREAT deal has been written on the steam-engine generally, but the author has not met with any connected record of the invention and construction of the first steam-engine—the atmospheric engine of Newcomen. Unfortunately it does not appear that very detailed information is available, but the author has been able to bring together some facts which, with the aid of appendices contributed by others and some illustrations of the engine itself, may be found to be a useful contribution to place on record in the *Proceedings* of the Institution. There are not many examples of the engine now in existence, and when they are consigned to the scrap heap, the receptacle of great efforts of the past, all will perhaps be forgotten.

Towards the end of the seventeenth century, philosophers and mathematicians searched for a new method of obtaining motive power. Mining was an important industry requiring in most cases a new power, that the mines might be worked to greater depths. Water-power, where available, was often insufficient, and manual and animal power was altogether too small and too expensive for working any but shallow mines. Deep mining was, and is, only possible with pumping machinery. Water-wheels were used for working pumps. The construction of the common pump was known. Papin had proposed to transmit power by means of pistons moving in cylinders acted on by the atmosphere, a vacuum having been formed under the pistons by the explosion of gunpowder, and he even hinted that it might be done by steam.

It was claimed for Papin that he invented the steam-engine, because in 1685, in one of his letters, he illustrated what was known of the properties of steam by saying that if water was put in the bottom of a cylinder under a piston, and the cylinder be put on a fire, the water would evaporate and raise the piston, and that if, after the piston had been raised, the cylinder were removed from the fire and cooled, the steam would condense and the piston would descend; but this was only an illustration of common knowledge. Sir Samuel Morland had, in 1683, stated[2] that steam occupied about two thousand times the space of the water from which it was produced, and made some calculations as to the powers to be obtained from different sized cylinders, but suggested no practical mode of operation. An experiment to determine the density of steam was made by John Payne in 1741. Payne concluded, as the result of his experiments, published in the *Phil. Trans.*, vol. xli. p. 821, that one cubic inch of water formed 4000 cubic inches of steam. Beighton calculated, from an experiment with the Griff engine, the second Newcomen engine erected, that the specific volume of steam was 2893.

The properties of steam were, probably, no better known to philosophers than to the ordinary observer who had seen the lid of a kettle dance under pressure, or steam issue from the spout. The only practical application of steam was made by Savery, who, in 1696, described his invention in a pamphlet entitled "The Miner's Friend." Savery's engine was a pistonless steam pump—in fact, the pulsometer of to-day without its automatic action. It remained for Newcomen to associate the bits of common knowledge in his mind for inventing the steam-engine. He was a blacksmith, probably accustomed to invent methods of construction in the prosecution of his art. At that time mechanics were more self-reliant than they are now. He knew from experience what a lever was, a pump, a piston, a cylinder, a boiler, and he knew that the atmosphere had pressure, and that steam possessed a far greater volume than the water which produced it. It did not require much more than common knowledge and observation to realise that. To produce the steam-engine from such known facts required invention. Philosophers probably knew what might be done, but Newcomen had the advantage of seeing what could be done, and he did it. The engine, when produced, was imperfect, but defects became obvious to the designers and constructor of steam-engines, and the want of perfection at the present day is not from want of theory, but because of practical limitations and want of practical invention.

At this distance of time it is difficult to appreciate the invention required to produce the atmospheric engine from the crude ideas of Papin and others. It appears, from papers in possession of the Royal Society, that Dr. Hooke had demonstrated the impracticability of Papin's scheme, and, in a letter addressed to Newcomen, advised him not to attempt to make a machine on that principle, adding, however, that if Papin could produce a speedy vacuum, his work would be done.[1] A great deal of controversy hangs about this as about all things historical, and little is to be gained by minute research into disputed claims. What we do with certainty know is that with the common knowledge existing, and the mechanical contrivances available, Newcomen alone succeeded in making a workable engine.

In 1698, Thomas Savery, of London, obtained a patent for raising water by the elasticity of steam.[2] It is stated in many popular histories that in 1705 Thomas Newcomen, John Cawley, of Dartmouth, and Thomas Savery, of London, secured a patent for "condensing the steam introduced under a piston and producing a reciprocating motion by attaching it to a lever," but no record of such a patent exists in the Patent Office. Stuart gives a list of patents commencing with 1698, and in that list is one said to have been granted in 1705. Dr. Pole, author of "The Cornish Engine," had a search made at the Patent Office and no such record could be found. It is possible that Savery's patent was thought to cover Newcomen's invention (as Savery was associated with Newcomen).[3] This was sixty-four years before Watt invented his separate condenser. Very little is known of Newcomen. It is recorded that he was a blacksmith or ironmonger residing at Dartmouth, in Devonshire, and that he was employed by Savery to do some work in connection with his water-raising engines. In this way he had some experience in the condensation of steam.[4]

Newcomen appears to have conceived the idea of using a piston for giving motion to pumps. He became associated with John Cawley, a glazier of Dartmouth, probably for business reasons. His connection with Savery was doubtless because of Savery's patent for condensing steam for raising water. He must, however, have been a good mechanic, because the construction of such an engine at a time when there was no previous experience or data to guide him was a task of no ordinary magnitude. He could not get workmen skilful enough to do his work until, erecting an engine near Dudley in 1712, he secured the assistance of mechanics from Birmingham.

The Newcomen engine was soon brought into use, for in 1712 Newcomen, through the acquaintance of Mr. Potter, of Bromsgrove, erected an engine, near Dudley Castle, for a Mr. Back, of Wolverhampton. The cylinder of this engine was surrounded with water. The piston was packed and had a water seal. It is reported that by accident a hole in the piston admitted water into the cylinder, and the condensation thereby became so rapid compared with that produced by cooling the cylinder from the outside that the engine worked much quicker. This may or may not be correct, but it is certain that, by accident or design, the first improvement in the engine was condensation by injection in the cylinder. It appears that the second engine was erected at the Griff Colliery, in Warwickshire, in 1715. It had a 22-inch cylinder. At this time the cocks and

[1] Abstract of a paper read before the Institution of Mechanical Engineers on October 16 by Mr. Henry Davey.

[2] See Tredgold's "Steam Engine."

[1] See Stuart's "History of the Steam Engine."

[2] Savery was born at Shilston, near Modbury, in Devonshire, in 1650; died in London 1715.

[3] It appears that there is every reason to believe that Newcomen had no patent, and that his invention was supposed to be covered by Savery's patent of 1698, and that the latter was kept in force for thirty-five years, the original patent having been extended for twenty-one years.

[4] Newcomen was born at Dartmouth about the middle of the seventeenth century, and died in London in 1729. It is stated in Haydn's "Dictionary of Dates" that at the time of his death he was in London trying to secure a patent. A sketch of the house in Dartmouth occupied by Newcomen when he invented the steam-engine is shown in a pamphlet published in 1869 for Mr. Thomas Lidstone of Dartmouth.

valves were all worked by hand, but automatic devices were soon introduced. The first appears to be that of actuating the injection-cock by means of a buoy in a pipe connected to the cylinder. Desaguliers thus describes the apparatus:—"They used to work with a buoy in the cylinder enclosed in a pipe, which buoy rose when the steam was strong and opened the injection and made the stroke." It is said that a boy, Humphrey Potter,[1] added a catch or "scoggan" which the beam opened, and by this means the speed of the engine was increased from 8 or 10 to 15 strokes per minute.

Barney's illustration of the Dudley Castle engine (erected in 1712) was made in 1719, and contains the plug-frame and tumbling-weight device attributed to the invention of Beighton in 1718. It is possible that the tumbling-weight had just been added for actuating the steam-valve. The injection-valve is released by the buoy said by Desaguliers to have been enclosed in a pipe attached to the cylinder, but here shown in a pipe attached to the boiler. The scoggan is also shown, and it is clear that the only thing that Humphrey Potter added, if he added anything, was a cord to cause the plug-frame to actuate the scoggan instead of the float doing it.

Newcomen had associated with him Cawley, a plumber and glazier, and it will be observed that the pipes of the engines were at first made of lead with plumber's joints. In the early days the steam cylinders only were obtained from iron-founders, and the other parts of the engine were built by local blacksmiths, carpenters, and plumbers, under the direction of an engineer.

The engine was first fixed on a boiler of haystack form, but the vibration of the engine so loosened the joints that it was found advisable to secure the cylinder to strong wooden beams above the boiler. At a later date the engine was fixed on a separate foundation by the side of the boiler, and as time went on iron pipes were substituted for lead, and the waggon-boiler was introduced to take the place of the haystack.[2]

Among the first erectors of the Newcomen engine were the Hornblowers, in Cornwall. Newcomen visited Mr. Potter, of Bromsgrove, and erected an engine near Dudley Castle in 1712. This is the historical engine in which injection in the cylinder was first used. In the vicinity lived Joseph Hornblower, an engineer who became acquainted with Newcomen's engine, and who was sent for into Cornwall about 1720 to 1725 to erect an atmospheric engine at Wheal Rose Mine, near Truro.

It may be interesting here to observe, on the authority of Cyrus Redding, a greatgrandson of Joseph Hornblower, and author of "Yesterday and To-day," &c., that the Newcomen engine was not such a simple machine as only to require the attention of boys as stated in popular histories, but that it required the united exertion of three men to start the engine.

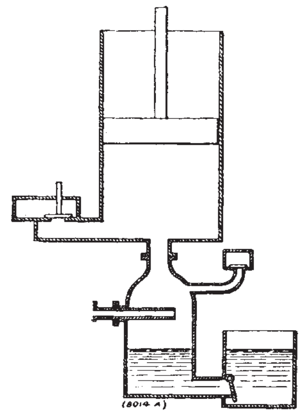
A second engine, it appears, was erected by Hornblower at Wheal Bury or Chasewater Mine. A third at Polgooth. Joseph Hornblower then left the county, and his son Jonathan came down and erected his first engine at Wheal Virgin, about 1743. The fourth son of Joseph was Jonathan Carter, the inventor of the compound engine and the double-beat steam-valves, who died at Penrhyn in 1815.

From 1720 to 1740 few engines were erected in Cornwall because of the high duty on sea-borne coal. In 1741 an Act of Parliament was passed for the remission of the duty on coal used for fire-engines for draining tin and copper mines in the county of Cornwall.[3] The effect of the passing of this Act was that by the year 1758 many engines had been brought into use; one engine at Herland had a 70-inch cylinder.

*Rotative Atmospheric Engines.*—It appears that attempts were made as early as 1768 to produce a rotative motion from a Newcomen engine, but it was not until about 1780 that it was successfully accomplished by the use of the crank.

It does not appear that any attempt was made, before Watt's separate condenser was invented, to reduce the cooling effect of the injection-water on the cylinder by effecting the condensation in a small vessel attached to the cylinder. It is, however, evident that after Watt's patent, Newcomen engines were made with separate condensers without air-pumps, the air being discharged through a snifting-valve. Such condensers were known as "pickle-pots."

FIG. 1.



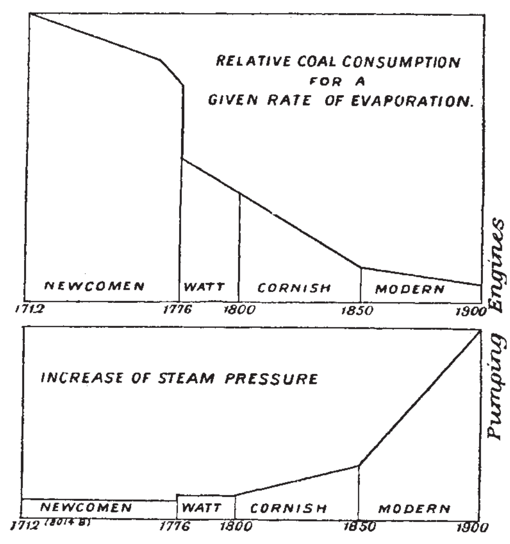



FIG. 2.

Diagrams illustrating the progress in economy of fuel and the increase of steam pressure.

In Fig. 1 will be found a sketch of the "pickle-pot" condenser. Such condensers were operated without air-pumps, as already described. It is more than probable that such condensers were not known until after Watt's invention of the separate condenser, and that they were applied to improve the economy of the Newcomen engine and to evade Watt's patent.

In Fig. 2 will also be found a diagram constructed by the author to indicate the economy of fuel resulting from various improvements commencing with the earliest engines of Newcomen. A diagram below also indicates

[1] It is curious to observe that the first engine was erected for Mr. Back through the influence of a Mr. Potter. Mr. Norris writes that John and Abraham Potter were engineers in Durham, and erected an engine for Mr. Andrew Wauchope in Midlothian in or about 1725. See also Bald's "View of the Coal Trade of Scotland," pp. 18, &c., for a full account of this engine. He prints the contract in full, giving many interesting details.

[2] A drawing of almost the first Watt engine for the Birmingham Canal was illustrated in the *Engineer*, July 15, 1898. This is now erected in the yard at Ocker Hill, near Wednesbury.

[3] The Act referred to is the 14th Geo. II., Cap. xli., and intituled:—An Act for granting to His Majesty the sum of one million out of the sinking fund, and for applying other sums therein mentioned for the service of the year 1741; *and for allowing a Draw-back of the Duties upon Coals used in Fire Engines for drawing Tin and Copper mines in the County of Cornwall, &c.* . . .

the rise in steam pressure corresponding to the increased economy.

The steam-engine has held its own as a prime mover for two centuries. The gas-engine has now become a more efficient heat engine, and a powerful competitor, and electricity has become an economical transmitter of power.

Heat, electricity, and mechanical work are mutually convertible. The time may come when heat may be converted into electric current with as little loss as that involved in the conversion of electric current into mechanical work; when that time comes, the heat efficiency of the prime mover will exceed that of the gas-engine in a greater degree than the gas-engine has exceeded that of the steam-engine.

## UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The Public Orator, Dr. Sandys, of St. John's College, spoke as follows in presenting, for the complete degree of Master of Arts *honoris causa,* Mr. Howard Marsh, recently elected professor of surgery in succession to Sir George Humphry, who died in 1896.

Haud ita pridem, ut meministis omnes, plenus annis, plenus honoribus, e vita excessit vir insignis, per annos plurimos primum anatomiam, deinde chirurgiam, inter nosmet ipsos praeclare professus. Qui qualis quantusque vir fuerit, quanto scientiae amore, quanta animi alacritate, quanta sermonis facundia praeditus, non est quod longius exsequar: vosmet ipsi vobiscum recordamini. Chirurgiae vero professoris nostri primi in locum, annorum septem intervallo interposito, nuper electus est vir egregius, quem, tot aliis ministrum salutis, Academiae nomine hodie ipsum jubemus salvere. Viri talis autem inter laudes, non nostrum erit hodie scientiae tam reconditae penetralia perscrutari, non artis intimae mysteria occulta et abstrusa in lucem proferre; ne corporis quidem mala illa dura verbis duris expressa, ut ἀρθρῖτις, ut ἀγκύλωσις, totiens ab hoc viro feliciter levata, coram vobis hodie commemorabuntur. Mentis potius ad bona praeclara transibimus, et professorem nobis nuper datum propterea praesertim animo laeto accipiemus, quod ingenio tam vivido, judicio tam subacto est praeditus, in rebus minutissimis observandis tam subtilis, in rebus obscurissimis explicandis tam lucidus. Viro in ea parte medicinae quae manu curat insigni manus libenter tendimus, dextraeque tam sollerti dextram libenter jungimus. Duco ad vos baronetti quidem illustris, Jacobi Paget, quondam adjutorem, equitis autem insignis, Georgii Humphry, nunc demum successorem, virum nobis omnibus acceptissimum, Professorem Marsh.

A special course of advanced lectures on certain general aspects of zoology, to be given at the zoological laboratory during the Michaelmas and Lent terms, on Tuesdays and Saturdays at noon, commenced on November 17. The course includes lectures by the following:—Mr. Brindley, regeneration; Mr. Doncaster, (1) Weismann and his work, (2) experiments with Echinoderm eggs and larvæ; Mr. Fletcher, cell-structure, cell-division and maturation of germ-cells; Mr. J. S. Gardiner, marine fauna; Mr. Hopkins, animal pigments; Mr. Punnett, metamerism; Mr. Shipley, parasites. The first two lectures are on parasites, by Mr. Shipley. The order of the other lectures will be arranged later.

Mr. Bertram Hopkinson, son of the late Dr. John Hopkinson, F.R.S., has been elected professor of mechanism and applied mechanics in succession to Prof. Ewing. Prof. Hopkinson was placed in the first division of the first class of the mathematical tripos, part ii., in 1895, and was *proxime accessit* for the Smith's prizes in 1896.

Mr. W. Morley Fletcher, Trinity, has been appointed demonstrator of physiology.

A Clerk Maxwell studentship for research in physics will be filled up at the end of this term. Applications are to be sent to Prof. J. J. Thomson by December 18. Candidates must have worked at least one term at the Cavendish Laboratory.

The special board for medicine proposes to establish a post-graduate examination and diploma in tropical medicine and hygiene, intended to meet the needs of military, colonial, and missionary practitioners. Mr. Chamberlain and Mr. Brodrick have expressed their approval of the proposal in the interest of the imperial medical services.

A syndicate consisting of Dr. Guillemard, Dr. A. Macalister, Dr. Haddon, Prof. Ridgeway, Mr. J. G. Frazer, Mr. A. E. Shipley, Mr. W. L. H. Duckworth, and Dr. Rivers, is proposed to consider the better organisation of the study of anthropology in the University.

THE Advisory Board on Military Education and Training, appointed by the Secretary of State for War in April last, has stated some of the conclusions which have been arrived at, and now carry the approval of the Secretary of State. With regard to the selection of the candidates for commissions through Sandhurst and Woolwich, it is proposed to subject them to a twofold test, consisting of a preliminary qualification and a competitive examination. The Advisory Board is of opinion that the subjects covered by the qualifying certificate (which is to be given not by a special examination, but some substitute in the shape of a "leaving certificate") must include:—(1) English; (2) history and geography; (3) mathematics (elementary); (4) French or German; (5) either (*a*) Latin or Greek, or (*b*) science. By "science" in this scheme is meant such combination of experimental or natural sciences as the Board may approve. Provided always that the sciences recognised shall have been taught in a sufficiently extended course, say three years, involving a sufficient amount of laboratory or field work. In the competitive examination the Board considers that for Woolwich candidates it should consist of three compulsory subjects, viz. English, either French or German, mathematics i., and of any two out of the following:—mathematics ii., science, history, French, German, Latin, Greek. For Sandhurst candidates they propose that there should be two compulsory subjects, viz. English, and French or German, with any two of the following:—mathematics i., mathematics ii., science, history, French, German, Greek, Latin. It consequently seems possible, and in view of public school traditions highly probable, that we may have young officers in training under the new regulations who are completely ignorant of scientific method.

SOME severe criticisms of our system of education for officers in the Army were made by Lieut.-Colonel F. N. Maude at the Royal United Service Institution last week in a lecture on "Military Education." He remarked that the rising generation of young officers as a body were leaving the public schools with less education than that of many of our rank and file. In his experience, Militia, Sandhurst, and Woolwich candidates were all willing to learn, and were easily interested in their work for a time, but as a body they were mentally incapable of "concentration" for more than a few minutes. He suggested that the Government should appoint a committee of the highest specialists in nervous diseases, loss of control, and similar troubles, and get them to report on the psychological, not the physiological, influence of "drill" exercises in restoring and developing will-power in the individual. Having secured concentration, what were they to teach? Primarily, they needed the power to observe facts accurately—*i.e.* scientific teaching; next, the knowledge of facts previously registered—*i.e.* history; and, thirdly, the power to reason accurately from given data—*i.e.* mathematics. But neither history nor science could be studied without a knowledge of modern languages. History was unintelligible without physiography, geography, and topography—hence these subjects should form integral parts of its teaching. Let the Government, he said, settle a course of instruction which could only be accomplished in the time by concentration of purpose on the decisive factors, and would require in every school a thoroughly modern equipment of educational means and appliances, and, to start the system, let it send its own experts round to advise and assist headmasters. In conclusion, he strongly urged the importance of securing for the Army a good supply of older university and Militia candidates, men who joined the service not only with a fuller sense of responsibility than one found in the average schoolboy, but also with a far wider and surer basis of knowledge.